New Technologies and Standards for Design Knowledge Management in Collaborative Conceptual Design

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Abstract

Current working methods and techniques in collaborative, distributed and knowledge intensive engineering design environment have a number of problems. Applications and techniques for managing the knowledge within the lifecycle are either too inflexible, and so remain unused, or completely uncoordinated resulting in the use of incoherent documents and filling systems to store information in an ad-hoc manner. This ongoing project, working with industrial partners, aims to provide a middle-ground application and methodology to enable users to define their ontologies from building blocks of RDF schema based components. This project also includes the use of STEP AP-224 models within the knowledge base to define the feature and geometry of the designed component and aims to integrate the process element using XPDL into the knowledge base in the future.

Keywords

Design knowledge management, STEP AP-224, RDF, XPDL, PLM

1 Introduction

Creating design concepts of complex engineering components and assemblies is a difficult and time consuming task. A massive amount of design knowledge is needed and also created by the engineers during the product development processes. This knowledge includes form, function, manufacturability and quality information. However, the great issue that faces companies today is how to co-ordinate the concurrent development of complex components and assemblies between the prime contractor, the supply chain and customer, whilst controlling the capture, organisation and reuse of the knowledge within the project. The technologies to enable enterprises to collaborate on designs with their supply chain and customers already exists in the commercial domain. Examples are Product Data Management (PDM) or Product Lifecycle Management (PLM) at the enterprise level, as well as productivity applications such as the new generation of collaborative Computer Aided Design (CAD) applications. These applications are fragmented however, and even the latest PLM systems are mainly used as document management tools that hold information in CAD files, Word and Excel documents which are inconsistent, impossible to query effectively and not machine understandable.

To overcome one of the major hurdles faced by enterprises in sharing knowledge, the World Wide Web Consortium (W3C) standard eXtensible Markup Language (XML) has been used as a method to exchange a range of textual information between business systems. The most important issues include interoperability between applications from different vendors without the need for specific interfaces and translators. The XML format which has been widely used for data exchange and persistence is machine readable by any XML parser; however readability alone does not create understanding of the meaning within the data. The result being that vendors and academics have continued to rely on producing specific interfaces for different XML vocabularies, meaning that any heterogeneous engineering application will have difficulty in retrieving and processing data in XML without lengthy and costly integration with all data sources.

In the product data sharing effort, the International Standards Organisation (ISO) STandard for the Exchange of Product model (STEP) Application Protocols (APs) have been implemented by CAD vendors in their solid modellers. However, the STEP standard(s) have also created some mixed results in industry. The Application Protocol (AP) -203 and -214 standards have been widely adapted by CAD vendors to generate geometric data, for configuration controlled geometric designs and automotive designs. However, these Application Protocols do not provide the necessary machining feature information needed for process planning and Numerical Control (NC) tool-path generation. AP-224 “machining features for Process Planning” protocol was created to bridge the gap between the design oriented AP-214 and the manufacturing process plans. The main problems that have dogged this effort have been the lack of effective automatic feature recognition technology available to the extended enterprise at low cost. Applications such as GibbsCAM and STEPTrans are proprietary and beyond the means of Tier-2 and 3 suppliers.

There have been insufficient efforts devoted to the creation of practical applications that push the manufacturing aspects of the development process higher up in the development chain despite the widely accepted view that manufacturability issues are a major bottleneck and cause of engineering changes within the development cycle. Therefore, the main objectives of this project are to develop new technologies and evaluate the new international product knowledge/data sharing standards for collaborative conceptual design and manufacturing evaluation.

2 Existing Theories and work

There have been a number of major studies and development efforts in concurrent product design within the supply chain and extended enterprise domains. Sanchez et al [1997] developed a knowledge based system (KBS) for the integration of manufacturability issues into the conceptual design phase of a project. [Brunetti, Golob 2000] developed a design-by-features tool intended for use as at the conceptual stage of development. The software captures conceptual design intent (requirements), functions, product structure, assemblies, and individual components with explicitly declared features. [Shyamsundar, Gadh 2001] developed cPAD (collaborative Product Assembly Design System). It is an internet based tool for the collaborative assembly design of mechanical assemblies and constraints between the Original Equipment Manufacturers and their supply chains. [Zha, Du 2001] have proposed a STEP based application to manage the entire product lifecycle using various STEP APs to define the product geometry, assembly and meta-data. The information that is not already defined in a STEP-AP is modelled in Express. Various other research efforts in Feature recognition technologies have been made by [Shah 1999], [Bhandrakar et al 2000].

Efforts have been made to solve the problems of analysing conceptual designs and reusing the generated designs in the embodiment design and manufacturing phases of the project. [Feng, Song 2000] developed a conceptual design activity model to describe the activities in the conceptual design phase. An object model in Unified Modelling Language (UML) was devised to embody this. [Rudolph 2000] tried to solve the problem of managing engineering data by creating an XML vocabulary to embody all the engineering terms in use, however problems would arise because of a number of factors: Engineering companies have different ideas of what defines their design data, and the XML vocabulary can be read only by systems already programmed to receive it and interpreted by a user or application familiar with the vocabulary. [Lihui 2002] has a review of current and near-future conceptual collaborative design applications.

The open-source software community, Open-Source Developer-Network [OSDN 2002] has a number of applications such as Open-source project and data management application TUTOS (as a backend server), open-cascade (solid modeller) and Protégé-2000 (graphical knowledge based system) which can be used as components within a collaborative conceptual design environment.

3 Research Approach

This study has focused on the problems of automotive and discrete machining companies in integrating their product realisation cycles with their supply chains and their customers in real-time, and also to enable the company to make rapid appraisal for their customers from simple concept designs. This embodies the transformation of the functional specifications into analysable concept designs for evaluation in a Computer Aided Process Planning (CAPP) system [Aziz et al., 2002; Cheung et al., 2002]. Also the system has to be able to reuse the company's existing base of knowledge and to push the manufacturing knowledge higher up into the design chain to reduce the need for costly and time consuming reworks and engineering changes. Initially a PLM system was used to test the basis of currently available systems for managing product data and business process in a development cycle [Gao et al., 2002]. An example project's data was evaluated and workflow created to model the development process of the company. Concentrating on the areas of knowledge capture, reuse and collaborative concurrent working environment, it became apparent that the real (technical) problems were not in communication technologies, but in the way knowledge is captured, managed and shared.

4 Test Application

The following test application has been created to test the viability of collaborative and concurrent engineering design and knowledge management using workflows and ontologies.

The client side applications are in Java/HTML (except the solid modeller), which ensures code portability between different platforms. Figure 1 illustrates the system architecture. The program is an orthodox client server model, based on the Windchill PLM system. It consists of an Oracle 8i database, Application Server, and the client side tools to create and manage the knowledge and product models.

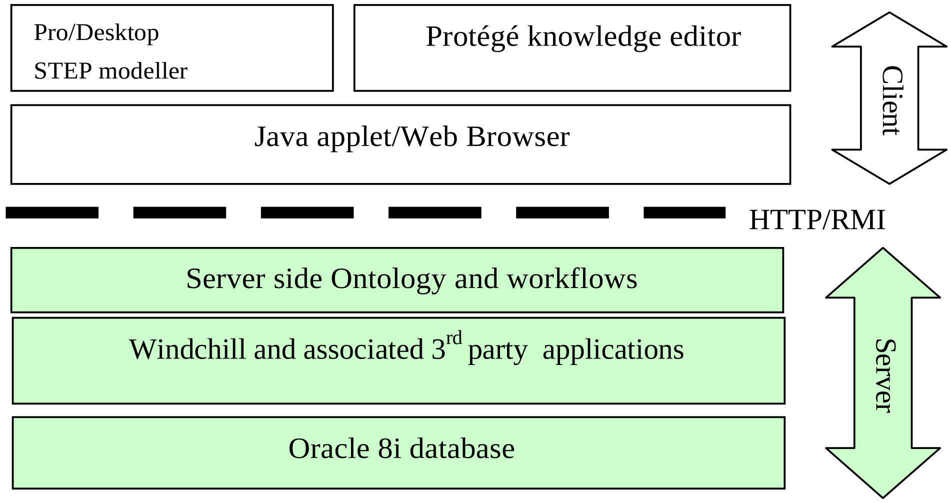

Figure 1, System Architecture

The PLM system was used to define the workflows and control the flow of information and sequence of the knowledge acquisition process. Java methods robots within the workflow were used to trigger Protégé client application with a specified knowledge base. The knowledge base is held in the vault and has the same access control, version and lifecycle management capabilities as any other document that can be held there. In addition this gives the normally single user protégé-2000 application a small amount of multi-user interactivity (however it is at this stage not truly multi-user). The client accesses the system using a Java enabled web browser and a protégé application. The user interface is the standard SWING form generated by Protégé Figure 2. For generating the geometry Pro/Desktop has been used as it's a free and lightweight modeller, with Part-21 AP-203 output.

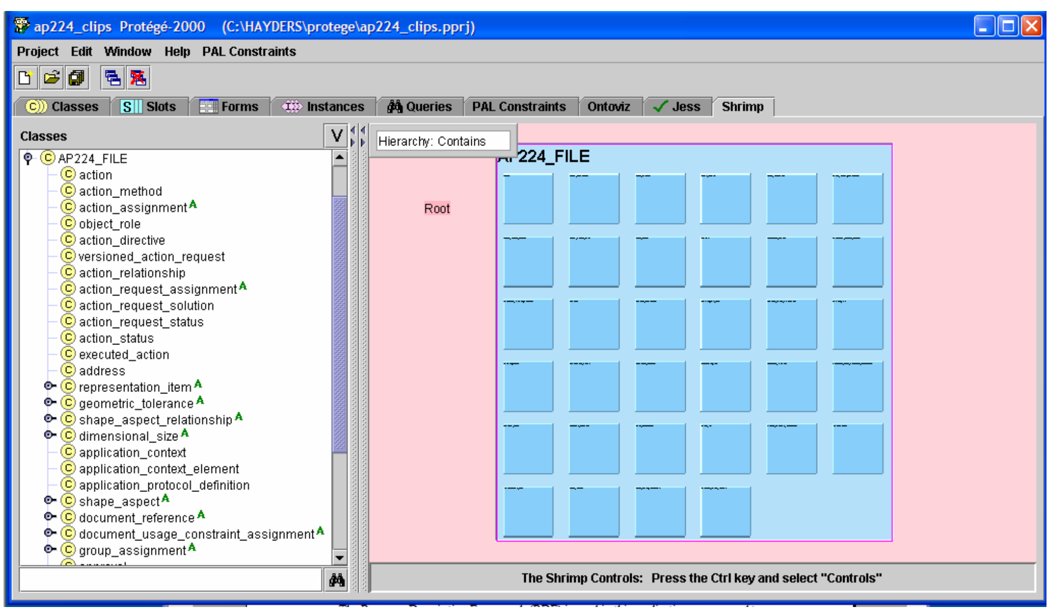

Figure 2, Protégé view of AP-224 model

4.1 Knowledge Model

The Resource Description Framework (RDF) Schema is used in this application, as opposed to basic XML for the ontology definition and storage. RDFS enables the storage of knowledge as unique instances within a subject-predicate-object triple commonly known as RDFgraph; the metadata. This is possible because the RDF model consists of the three parts mentioned above, The subject is a Universal Resource Identifier (URI) of the object which identifies the environment or context of the model, the predicate is a directed graph from the subject to the object and is also URI, it identifies the object's relationship to the subject, and the object is the data (in any of the defined formats). In "vanilla" XML only the "object" component can be defined within an entity, and it has neither a subject nor a predicate to enable an application to understand its context.

RDF has been modelled in this instance using the Protégé-2000 KBS system from Stanford Medical Informatics Laboratory and visualisation was made with GraphViz from AT&T.

The knowledge model has been captured using interviews with domain experts at the collaborating company and a capture of domain data from current and historical projects which were primarily stored in word processor and spreadsheet documents as well as paper based documentation. The knowledge model was then constructed in protégé and refined with extra documentation provided by the collaborating company.

Due to the size and complexity of the company's product development plan, only a small subset of its knowledge model was captured, primarily dealing with knowledge used and generated during the specification and conceptual design phases of their projects.

For the feature information, the STEP AP-224 standard was modelled into an RDF schema allowing valid AP-224 models to be created using the same knowledge base system as used for the company's non-geometric data. This integration at low level between the geometric, feature and "meta-data" within a single environment is intended to reduce repetition, errors and also enable the reuse of all the data created during the conceptual design process. As an example much of the rework done on the company's knowledge base was designed to eliminate entities already defined by STEP, this way information did not have to be re-entered into the system using the solid modeller AND the knowledge management system.

Figure 3 below shows a small detail of the AP-224 standard entities as modelled in RDF (the visualisation is using GraphViz).

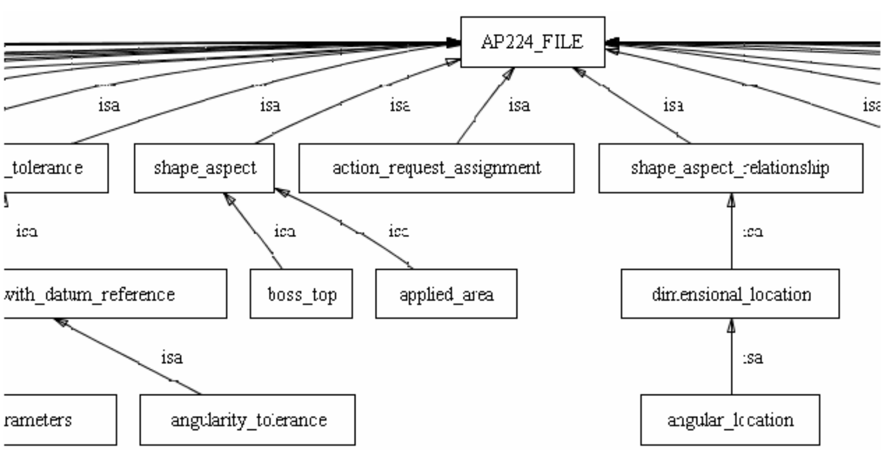

Figure 3, AP-224 entities as modelled in RDFGraph

The AP-224 standard contains a number of entities, types, functions and rules. The types were defined as a separate class for each type, and so were the entity classes. The types were defined

Enforcement of constraints cannot be done using pure RDF and therefore a number of other languages were used to enforce these, namely the Protégé Axiom Language (PAL) and also CLIPS rules. The definitions for the constraints and rules are contained in a separate CLIPS file. The STEP functions have been defined in as CLIPS rules using the Java Expert System Shell embedded in Protégé-2000.

4.2 Product and Project management

The test case company's workflows have been modelled using the Workflow Management Coalition's XML Process Description Language (XPDL). However the current Windchill release did not support XPDL and therefore, for the simulation purposes, had to be remodelled into Windchill's proprietary Java based workflow model. Nonetheless XPDL workflow will be used in the future stages of the project's development.

5 Findings

The above methodology and tools are still in development and have so far proven to be intuitive to use and flexible in the storage and processing of design and manufacturing knowledge. The application of disparate software components held together by a PLM system both for vaulting and workflow has shown some promise, however some of the open-standard tools such as XPDL workflows are still to be deployed due to the lack of available functionality in this particular PLM implementation.

The flexible RDF based knowledge base has enabled the creation of mixed geometric-knowledge models. Even though such techniques have been tried in the past the unique flexibility of using the RDF format for knowledge creation and persistence has opened up the possibilities for sharing and creating and analysing such meta-data and product models in a way that had required proprietary application servers and specific interfaces in the past. In addition the methodology in itself is application independent and any RDF capable editor and STEP compliant CAD system may be employed by users.

6 Future developments

The implementation described briefly in this paper was the first application in a 3 year development looking at future trends and techniques for collaborative product development and knowledge management. The results so far have pushed the direction of future work on the project into de-centralised project and knowledge management tools, primarily into the realm of Peer-to-Peer networks for truly distributed design and knowledge management. Also the experience of using a multitude of different proprietary data, communication and programming languages and standards have resulted in an absolute emphasis on utilising open standards throughout for construction of the applications, data storage models and communications protocols. The authors feel that any extra functionality offered by proprietary solutions such as .NET are more than offset by the long term utility and large scale uptake of any tool, in addition to interoperability and extraction of knowledge when the system reaches obsolescence. Thirdly, maximum utilisation of open-source technology to enable the rapid uptake of tools and techniques both by large companies, and their supply chains. This point is very important as many new technologies and communication/collaboration tools remain beyond the reach of a large section of the extended enterprise, reducing the viability of the expensive PLM solutions that the larger organisations invest in, but which cannot then effectively collaborate with their poorer suppliers.

7 Conclusions

The new methodology for creating, disseminating and managing product data from the conceptual stage has shown promise and further development of an open-source based application will create the necessary infrastructure to enable completely open-source and standards based product design and knowledge management within the enterprise, and also with the outside world, without the problems of interoperability, proprietary interfaces, and distribution of knowledge.

As stated earlier, the application and methodology are still in development and the final result will be a very different application, possibly shifting from a centralised to a peer-to-peer model, and the ontologies will be further developed with the collaborating partners.

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